EXAMPLE 17 INTERNAL CABLE BRACING

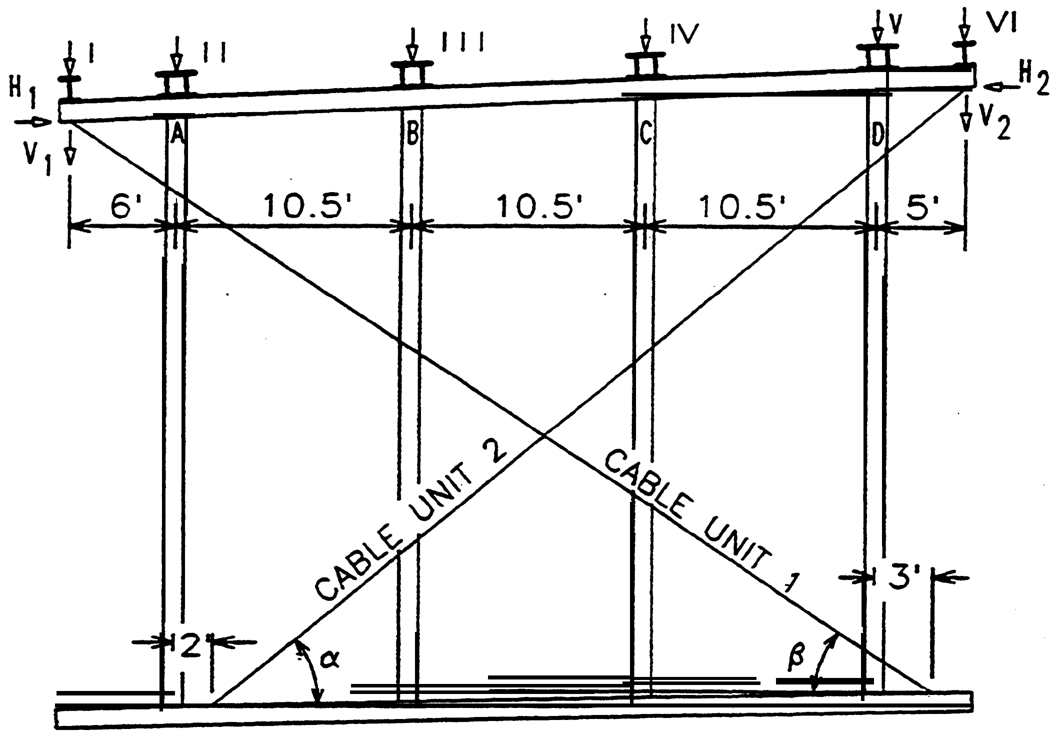


FIGURE 1

FALSEWORK BENT NOT ADJACENT TO TRAFFIC

Given

Posts = 12" ϕ Steel sections with wall thickness of 1/4"
Left Post height = 25 feet
Cap slope = + 4% to the right
Sill slope = + 2% to the right
Cap and Sill = W14 x 53
Preload Cables 1 to 1,000 Lbs and Cables 2 to 1,083 Lbs
Cables: One per side, all new l/2" ϕ wire rope

TABLE 1 **LOADS FROM STRINGERS (KIPS)**

STRINGER LOCATIONS	I	II	III	IV	V	VI
TOTAL DL + LL	20	73	76	90	69	19
TOTAL DL ONLY	17	61	64	75	59	16
BOTTOM SLAB & STEM DL + LL	13	51	46	55	42	11

Section Properties

Cap: I = 541 In^4, Weight = 53 Lbs/LF

Posts: A = 9.23 In^2, S = 26.56 In^3, r = 4.16 In

Cable Data from Manufacturer:
Cables are IWRC 6 x 19
Breaking strength = 11.50 Tons
Metallic area of cable = 0.118 In^2
Cable weight = 0.46 Lbs/Ft
Modulus of elasticity = 13.5×10^6 psi
(12.2×10^6 psi up to 20% of ultimate load
Constructional stretch = 0.5%
Safety factor = 3

Efficiency of cable and connectors:
Equivalent thimble diameter efficiency = 95%
Cable clip efficiency (Table 4-1) = 80% USE

Dimensional Analysis

Use geometry to compute post heights, cable angles and cable lengths.

Post Heights: A = 25.00'
B = 25.21'
C = 25.42'
D = 25.63'

Vertical components of cables from horizontal bases:

Cable Unit 1: 25.00 - ((3)(10.5) + 3)(0.02) - 6(0.04) = 24.07'

Cable Unit 2: 25.00 + ((3)(10.5) + 5)(0.04) - 2(0.02) = 26.42'

Angles shown in Figure 1:

$\beta = \tan^{-1} 24.07/40.50 = 30.72°$

$\alpha = \tan^{-1} 26.42/34,50 = 37.44°$

Cable Lengths (assuming no drape):

Cable Unit 1: 40.50/cos 30.72° = 47.11'

Cable Unit 2: 34.50/cos 37.44° = 43.45'

Design Horizontal Load

Assume the 2% loading controls.

Total dead load of the structure (from Table 1) = 292 Kips
2% of total dead load = (292,000)(0.02) = 5,840 Lbs.

Cable Capacity

The cable capacity is determined for static loading conditions by using the breaking (ultimate) strength divided by an appropriate factor of safety, in this case 3 as recommended by the manufacturer.

$$\text{Working capacity} = \frac{(11.5 \text{ Tons})(2{,}000 \text{ Lbs/Ton})}{3}$$

$$= 7{,}667 \text{ Lbs}$$

Working load = (80%)(7,667) = 6,134 with Crosby clips

Capacity of cable unit (2 cables) = 2(6,134) = 12,268 Lbs

Effects of Cable Stretch

1. Verify Cable Pre-Load Forces

Cables 1 designated preload = 1,000 Lbs each.

The preload in Cable Unit 2 must be such that the horizontal component of Cable Unit 2 balances that of Cable Unit 1.

Preload the individual cables of Cable Unit 2 to:

$$\begin{aligned}\text{Preload} &= 1{,}000 \cos\beta/\cos\alpha \\ &= 1{,}000 \cos 30.72°/\cos 37.44° \\ &= 1{,}083 \text{ Lbs} \approx 1{,}080 \text{ Lbs each}\end{aligned}$$

2. Cable Design Load

Cable loads due to design horizontal load:

Cable 1 = (5,840/cos 30.72°)/2 = 3,397 < 6,134 Lbs

Cable 2 = (5,840/cos 37.44°)/2 = 3,678 < 6,134 Lbs

Vertical Component of Cable Loading

Cable Unit 1 = (5,84O)(tan 30.72°) = 3,470 Lbs

Cable Unit 2 = (5,840)(tan 37.44°) = 4,471 Lbs

3. Cable Stretch

The cable will experience two 'stretchs conditions', elastic stretch and constructional stretch.

Elastic stretch

For loads up to 20% of the ultimate, use a modulus of elasticity equal to (0.90)E. For the remainder of the load use the full value of E. The two equations for elastic stretch are as follows:

$$\Delta_1 = \frac{[(20\%\ \text{Ultimate Load}) - (\text{Preload})](L)}{A(0.90E)}$$

$$\Delta_2 = \frac{[(\text{Cable Load}) - (20\%\ \text{Ultimate Load})](L + \Delta_1)}{AE}$$

20% of ultimate load = (0.20)(11.5 tons)(2,000 Lbs/ton)
= 4,600 Lbs

$$\text{Cable 1 } \Delta_1 = \frac{(3397 - 1000)(47.11)}{(0.118)(0.90)(13.5\text{x}10^6)} = 0.08 \text{ Ft}$$

$$\text{Cable 2 } \Delta_1 = \frac{(3678 - 1083)(43.45)}{(0.118)(0.90)(13.5\text{x}10^6)} = 0.08 \text{ Ft}$$

Constructional stretch

Assume that the total constructional stretch comes out at 65% of the ultimate load and that the stretch is proportional for the amount of load applied.

Constructional stretch:

65% of nominal load = (0.65)(11.5 tons)(2,000 Lbs/ton)
= 14,950 Lbs

Constructional Stretch = (Proportional Load)(0.5%)(L)

$$\text{Cable Unit 1} = \left(\frac{3,397}{14,950}\right)(0.005)(47.11) = 0.05 \text{ Ft}$$

$$\text{Cable Unit 2} = \left(\frac{3,678}{14,950}\right)(0.005)(43.45) = 0.05 \text{ Ft}$$

Total stretch

Cable Unit 1 47.11 + 0.08 + 0.05 = 47.24 Ft

Cable Unit 2 43.45 + 0.08 + 0.05 = 43.58 Ft

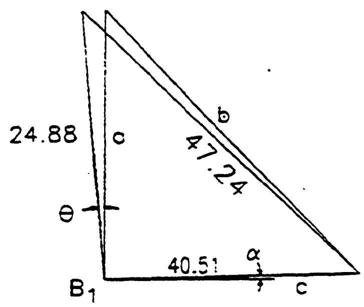
Note that the effects of cap or sill bending can generally be ignored for short cantilever conditions.

Cap Movement

a = vertical distance between the cable connection at the cap and the point on the sill directly below it.

b= cable length after stretch

c = the slope distance between the point on the sill described for a, and the cable connection on the sill.



Cable Unit 1 Loaded

$a = 25.00 - (6)(0.04) + (6)(0.02)$

$= 24.88$ Ft

$C = 40.5/\cos\alpha$

$= 40.50/\cos 1.15°$

$= 40.51$ Ft

$$B_1 = \cos^{-1}\left[\frac{a^2 + c^2 - b^2}{2ac}\right] \text{ Law of Cosines}$$

$$= \cos^{-1}\left[\frac{(24.88)^2 + (40.51)^2 - (47.24)^2}{(2)(24.88)(40.51)}\right]$$

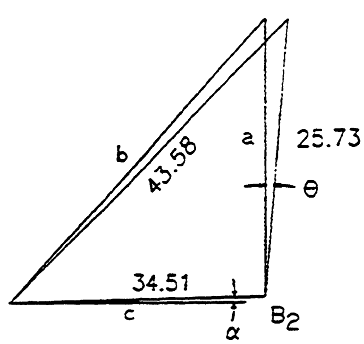
$= 89.19°$

$\theta = B_1 - (90° - \alpha)$

$= 89.39° - (90° - 1.15°) = 0.34°$

Cap Displacement = 24.88 Sin 0.34°

= 0.148 Ft = 1.78 In.



Cable Unit 2 Loaded

$a = 25.63 + (5)(0.04) - (5)(0.02)$

$= 25.73$ Ft

$c = 34.50/\cos\alpha$

$= 34.50/\cos 1.15°$

$= 34.51$ Ft

$$B_2 = \cos^{-1}\left[\frac{a^2 + c^2 - b^2}{2ac}\right] \text{ Law of Cosines}$$

$$= \cos^{-1}\left[\frac{(25.73)^2 + (34.51)^2 - (43.58)^2}{(2)(25.73)(34.51)}\right]$$

$= 91.49°$

$\theta = B_2 - (90° + \alpha)$

$= 91.46° - (90° + 1.15°) = 0.34°$

Cap Displacement = 25.73 Sin 0.34°

= 0.153 Ft. = 1.84 In.

Determine Post Adequacy for Loaded Cable Condition

1. Post Loads

Moment distribution was used to compute the post loads resulting from the bottom slab and stem reactions along with the vertical component of one loaded cable unit. The process was repeated with the other cable unit loaded.

ABLE 2 POST LOADS - BOTTOM SLAB AND STEMS + CABLE LOAD

POST REACTIONS, LBS	POST A	POST B	POST C	POST D
LOAD CABLE 1 ONLY	79,685	33,543	50,929	59,566
LOAD CABLE 2 ONLY	73,564	37,559	46,737	66,863

Stresses In Posts

Evaluate each post by using the combined stress expression:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1$$

Where:

$$f_a = \frac{P}{A} \text{ and } F_a = 16{,}000 - 0.38\left(\frac{L}{r}\right)^2 \text{ psi}$$

$$f_b = \frac{Mc}{I} = \frac{Pec}{I} = \frac{Pe}{S} \text{ and } F_b = 22{,}000 \text{ psi}$$

Sample calculation for stress in Post A with Cable Unit 1 loaded:

P = 79,685 Lbs, e = 1.78 inches

Using the combined stress expression:

$$\frac{\frac{P}{A}}{F_a} + \frac{\frac{Pe}{S}}{F_b} \leq 1$$

$$\frac{\frac{79{,}685}{9.23}}{14{,}024} + \frac{\frac{79{,}605(1.78)}{26.56}}{22{,}000}$$

0.62 + 0.24 = 0.86 < 1.00

Table 3 lists the results for all four posts for both directions of horizontal loading.

The stesses in all posts are satisfactory for this condition of loading.

TABLE 3 SUMMARY OF STRESSES

POST	A	B	C	D
F_a	14,024	13,990	13,957	13,923
F_b	22,000	22,000	22,000	22,000
CABLE UNIT 1 LOADED				
f_a	8,633	3,634	5,518	6,454
f_b	5,340	2,248	3,413	3,992
COMBINED STRESS	0.86	0.36	0.55	0.65
CABLE UNIT 2 LOADED				
f_a	7,970	4,069	5,064	7,244
f_b	5,096	2,602	3,238	4,632
COMBINED STRESS	0.80	0.41	0.51	0.73

Note that stresses in the cap and sill still need to be analyzed separately for both directions of cable loading.

2. Total DL + LL Post Loads and Stresses

Table 4 lists the results of placing the total section (dead and live loads) on the translated posts.

TABLE 4 SUMMARY OF STRESSES

POST	A	B	C	D
F_a	14,024	13,990	13,957	13,923
F_b	22,000	22,000	22,000	22,000
CABLE UNIT 1 LOADED				
Reaction	113,494	58,670	81,436	99,122
f_a	12,296	6,356	8,823	10,739
f_b	7,606	3,932	5,458	6,643
COMBINED STRESS	1.22	0.63	0.88	1.07
CABLE UNIT 2 LOADED				
Reaction	107,374	62,686	77,245	106,419
f_a	11,633	6,792	8,369	11,530
f_b	7,439	4,343	5,351	7,372
COMBINED STRESS	1.17	0.68	0.84	1.16

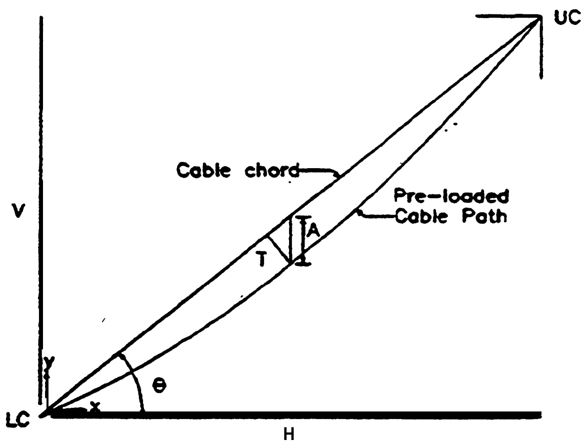
When cable Unit 1 is loaded, posts B and C are not considered to be overstressed for this condition of loading.

When Cable Unit 2 is loaded, post B is the only post not considered as being overstressed for this condition of loading.

Verifying Preload Condition

An aid to ascertain if the appropriate pre-load is applied to the cable is to determine and verify the amount of sag from the straight line between the cable connection points.

Use the equation expressed below to determine the distance from the chord to the loaded cable:



Where:

- q = Cable weight per foot
- T_H = Horizontal force in the cable
- y = Vertical distance above the cable-sill connection
- x = Horizontal distance from the cable-sill connection
- H = Horizontal distance between cable ends
- V = Vertical distance between cable ends
- UC = Upper cable connection
- LC = Lower cable connection
- T = Offset normal to the chord between cable connection points

For one preloaded cable of Cable Unit 2:

$$T_H = 1{,}080 \cos 37.44°$$
$$= 1{,}715 \text{ Lbs}$$

$$A = \left(\frac{0.46x}{1715}\right)(34.5 - x)$$

For x = 17.25

$$A = \left(\frac{(0.46)(17.25)}{1715}\right)(34.5 - 17.25)$$
$$= 0.08 \text{ Ft}$$

$$\text{Offset} = A \cos \theta$$
$$= 0.08 \cos 37.44° = 0.06 \text{ Ft}$$

A table may be generated for offsets of the cable from the chord at distances along the horizontal axis if accurate amount and location of maximum sag is desired.

x	Sag (A)	Offset
0	0.00	0.00
3.45	0.03	0.02
6.90	0.05	0.04
10.35	0.07	0.05
13.80	0.08	0.06
17.25	0.08	0.06
20.70	0.08	0.06
24.15	0.07	0.05
27.60	0.05	0.04
31.05	0.03	0.02
34.50	0.00	0.00

For close approximation assume that for preloaded cables the maximum sag occurs at the center of the horizontal distance between connection points.